Automatic detection of microemboli by means of a synchronous linear prediction technique

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1. Introduction

Detection of microemboli is of great clinical importance to prevent cerebro-vascular events and to identify the causes of such events. As standard detection techniques implemented in the most commonly used systems cannot detect all of microemboli events whose energy is lower than the systolic energy, new techniques are proposed.

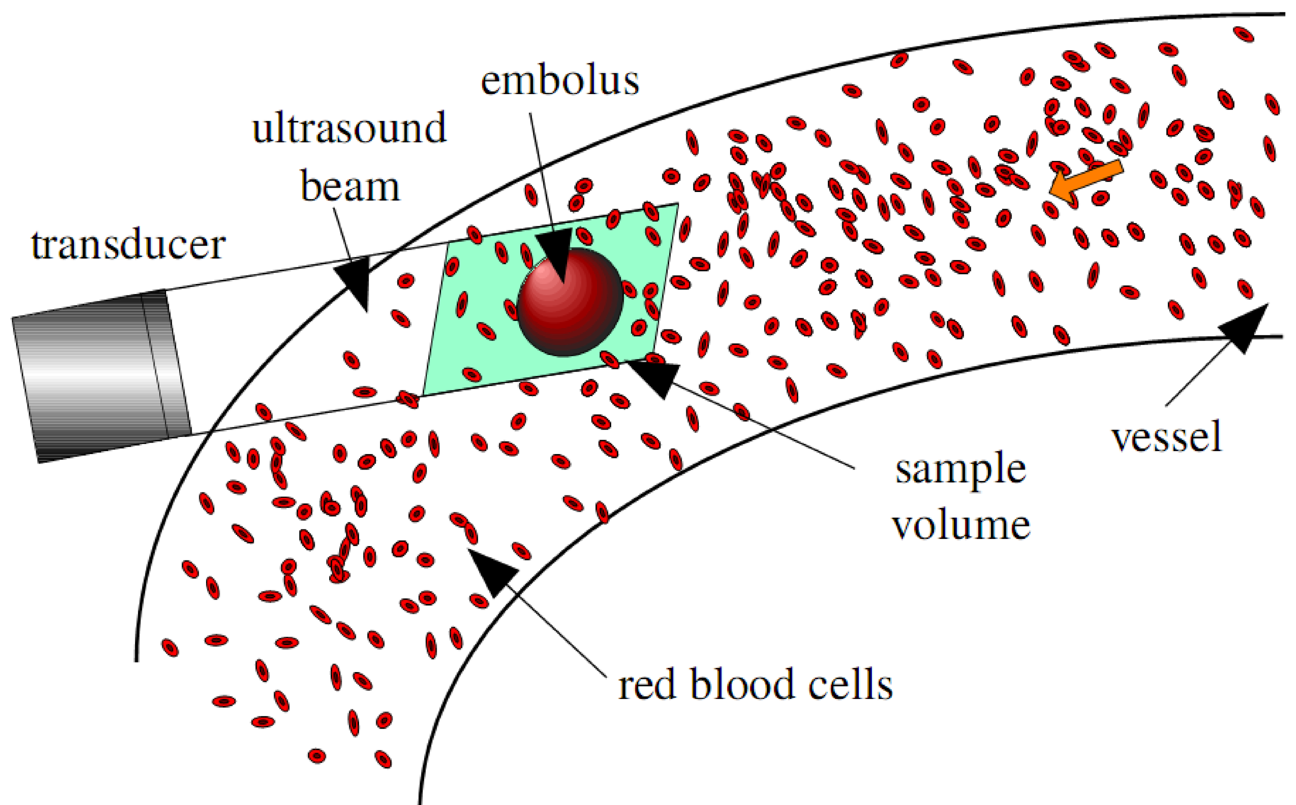
Joint used of synchronous and linear prediction techniques could detect very small microemboli. If we periodically take and compare the values of the energy of the prediction error (or autoregressive parameters) at different time points in the cardiac cycle, we can therefore detect the presence of non-periodic events such as microemboli.

In our study, we tested and compared our new technique to the standard technique (Fourier) using simulated and in vivo signals from patients with stenosis of high degrees of severity.

2. Materials

TansCranial Doppler system (TCD)

- Velocity of blood flow through the brain's arteries
- Pulsed Doppler probe
- Examination in the temporal region
- used TCD : Waki^{TM}(Atys Medical, Soucieu en Jarrest, France)



A photograph at time t

Doppler signals

- The Doppler signals are cyclo-stationary
- Synthetized Embolus Doppler signal proposed by Wedling
- *In vivo* Doppler signals from patients stenosis of degrees IV of severity

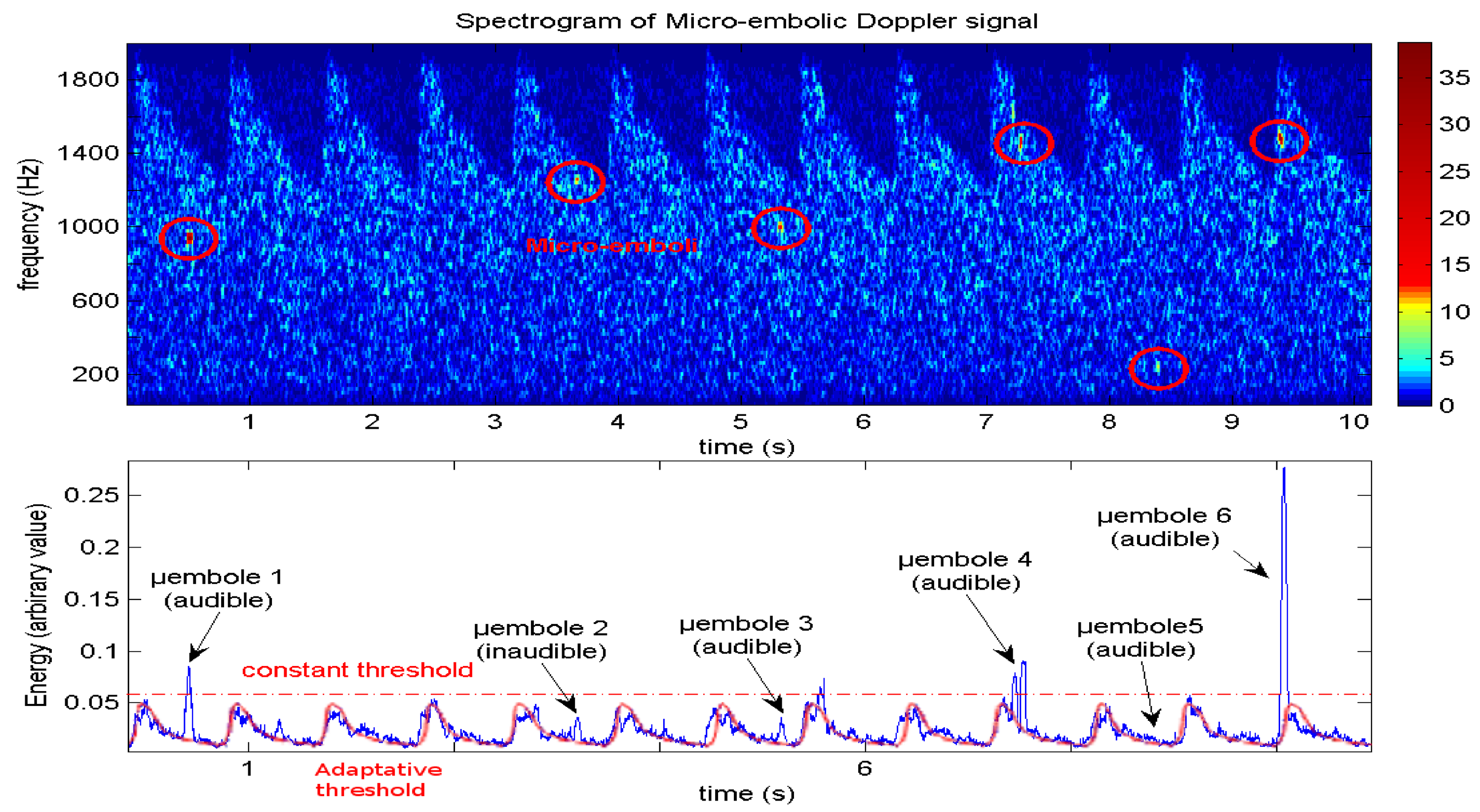
3. Methods

Gold standard test

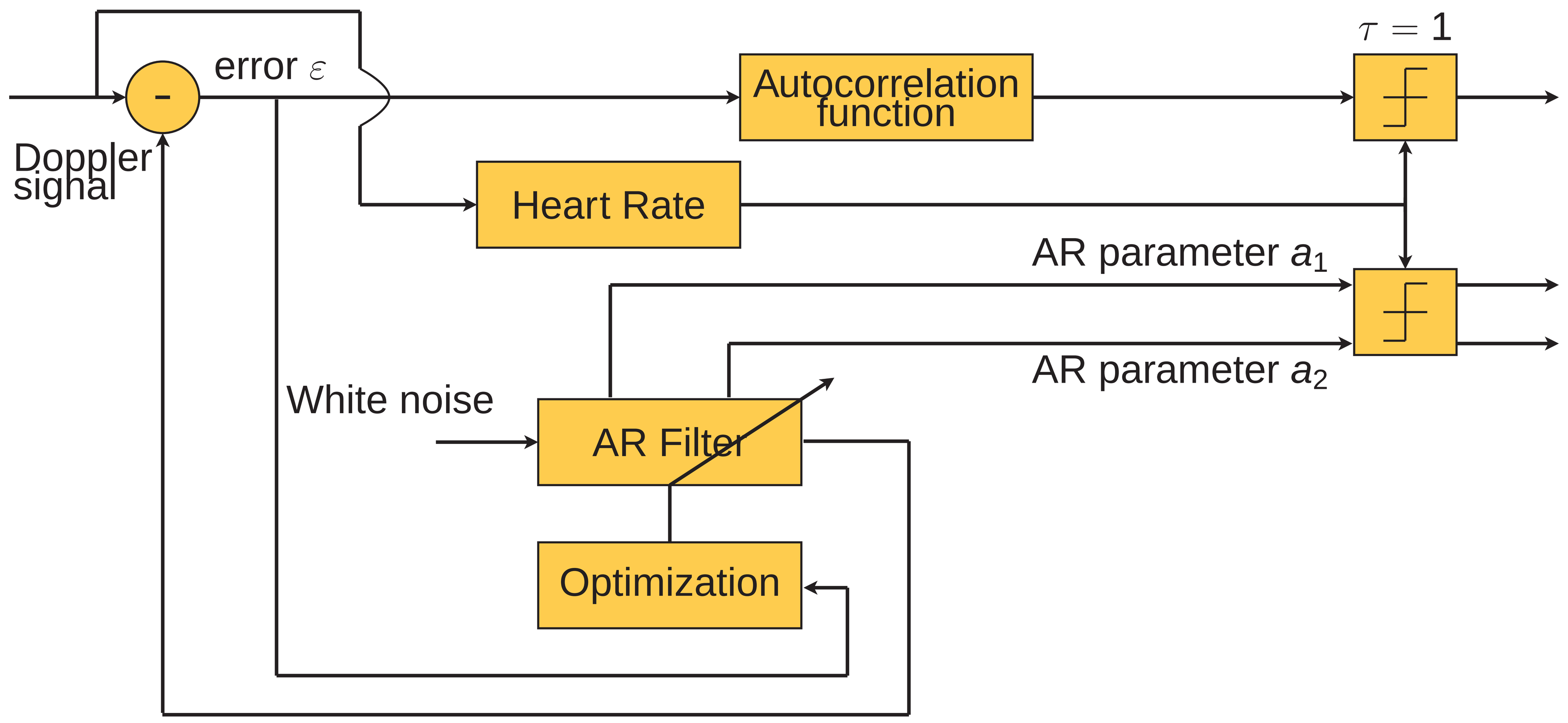
Manual embolus detection by audible detection and sonogram visualization

standard technique

1. Computation of energy by Short Time Fourier Transform
2. Constant threshold λ set between 3 to 9 dB above the maximal energy $\rightarrow$ reduce the false alarm probability
3. Embolus detection when energy upper than the threshold λ



Synchronous linear prediction technique (SLP)



1. Computation of energy by Short Time Fourier Transform
2. Model of signal with 2nd-order AR model

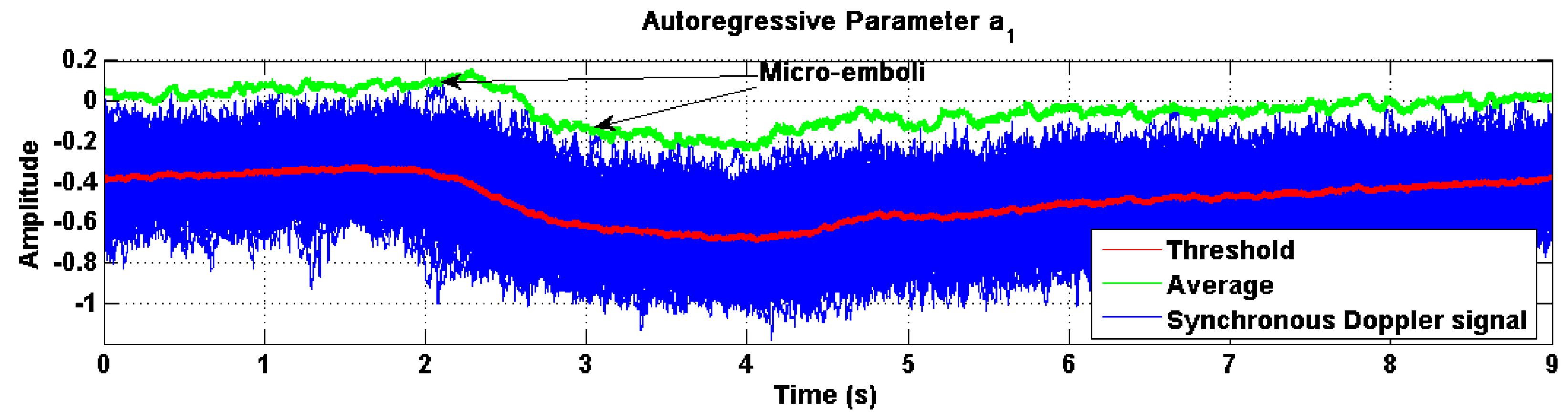
$$x(n) = -a_1(n)x(n-1) - a_2(n)x(n-2) + \varepsilon(n)$$

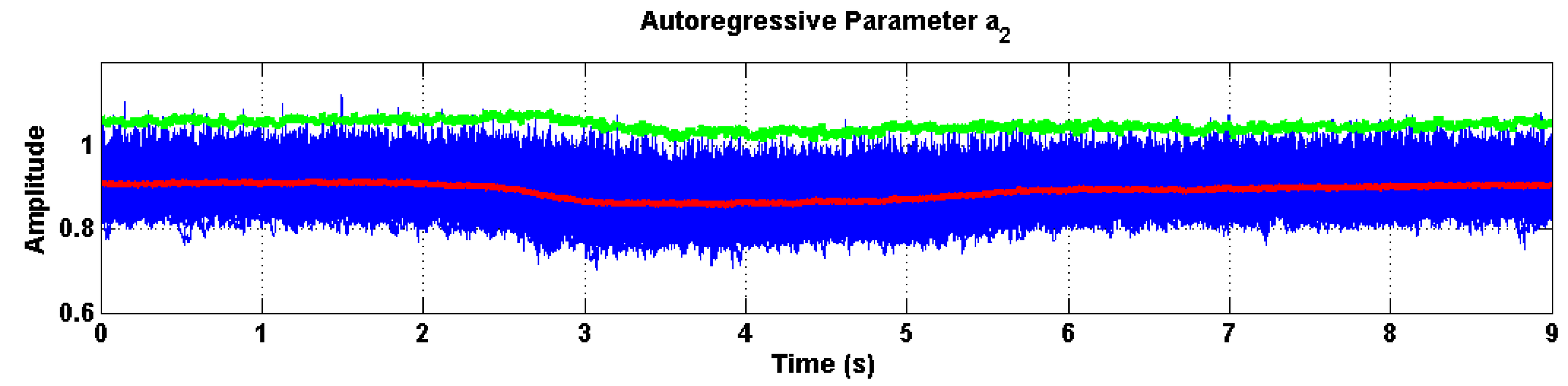
3. Error Autocorrelation $\Gamma_{\varepsilon\varepsilon}(n) = \sum_{m=-\infty}^{+\infty} \varepsilon(m)\varepsilon^*(m-n)$
4. Synchronization with the cardiac cycle
5. Detection by a time-varying threshold $\lambda(t) = \mu(t) + \beta\sigma(t)$ with $\mu(t)$ the average and $\sigma(t)$ the standard deviation

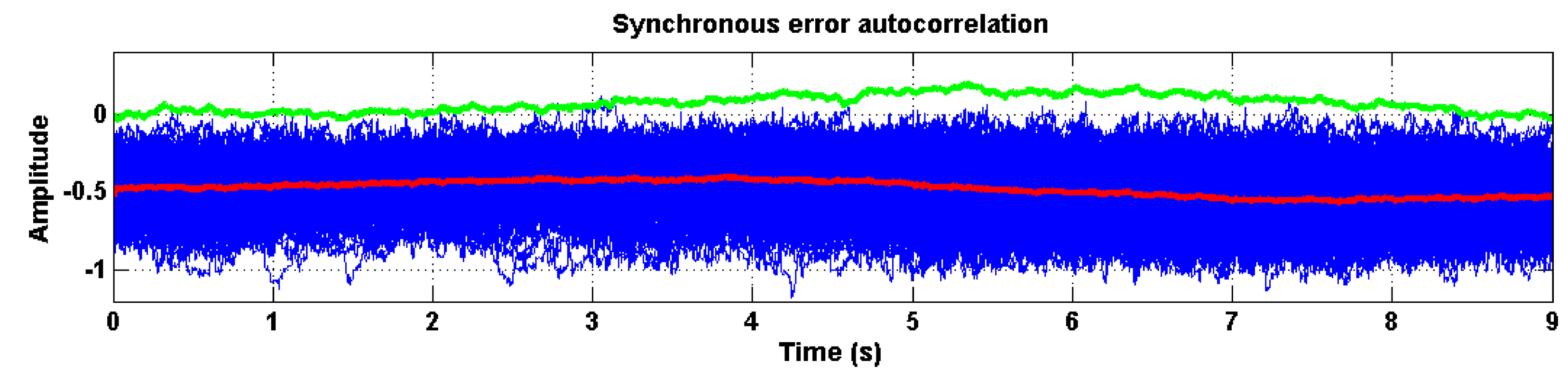
4. Results and Discussion

In simulation

	Gold standard	standard	SLP a_1	SLP error
embolus detection	100 %	100 %	100 %	100 %
false alarm rate	0 %	32.37 %	7.49 %	5.80 %







In vivo

	Gold standard	standard	SLP
embolus detection	100 %	67 %	100 %
false alarm detection	0 %	0 %	0 %

Discussion

- Best detection with SLP : embolus can be detected even if it was inaudible up to now
- Synchronous error autocorrelation does not improve the detection: the error does not vary with the cardiac cycle

5. Conclusion

- Large microemboli are all detected
- Small microemboli are only detected with our new technique
- incorporate "on line" technique

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